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ABSTRACT

This newsletter summarizes findings from the research on secondary school mathematics published during 1971 that might be used by teachers. Covered is research on behavioral objectives, individualized procedures, comparisons of "modern" and "traditional" programs, activity learning procedures for teaching geometry, learning of logic, computer-aided instruction, homework, test development, student attitudes, problem solving, and patterns of teacher behavior. A list of 39 references is included. The Center's mathematics laboratory project is also described. (DT)

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From The Research Of 1971 On Secondary School Mathematics

In a review of the research on secondary school mathematics, Suydam (1972) summarized findings from the research on secondary school mathematics published from 1930 through 1970. This was presented in question-and-answer format.

This newsletter presents some of the questions and answers from research published during 1971. The focus is on research that the teacher might use; there are other studies of interest principally to researchers, which are not included. An attempt has been made to take into consideration the variability in the quality of research as this newsletter was prepared.

Does the use of specified objectives facilitate achievement?

There has been a vast amount of attention in the literature on the use of behavioral objectives, yet comparatively little research attention directed explicitly toward ascertaining their usefulness. In one such study, McCullouch compared the achievement of ninth grade groups using a curriculum based on behavioral objectives and groups using a standard textbook program (which was also based on objectives, though presumably not behaviorally-stated objectives). He found no significant differences in their achievement, though groups using the behavioral objectives curriculum made greater progress in arithmetic fundamentals and reasoning.

Collins reported that use of either a list of specific objectives or diagnostic-progress tests was sufficient for a significant increase in mastery of objectives by seventh graders. Eighth graders also profited from the use of alternative resources.

How effective are individualized procedures?

Various types of procedures which attempted to individualize instruction in various ways for various groups of students were studied. Because of the variability, it is difficult to make any generalizations.

Baker reported no significant differences in achievement, confidence, or interest between groups of low-achieving ninth graders who selected their own activities and those who could select problems or had no choice. The students most frequently chose teacher-made assignments for the activity. He suggested that this may indicate a strong dependence of the low achiever on the guidance and direction of the teacher.

Bull studied an individualized geometry program in which the student paced his own learning, chose learning experiences to attain teacher-established objectives, and took tests when he felt prepared, with the teacher primarily helping individuals and small groups. He found that the mean score of classes taught by the individualized method was significantly higher than that of classes taught by the traditional method.

Gould found that achievement gain for ninth graders taught two days a week under a "supervised study" plan with assistance from fellow students in small groups, was significantly greater than that of students taught under a "daily recitation" plan. No significant difference in change in attitude toward mathematics was found between the two groups.

Olson found that achievement and attitude were not significantly different in geometry classes in which students studied in pairs or alone. On a related topic, Ellis found that for classes in grades 9 through 11 in which above-median students tutored below-median students, greater achievement gains were made than in classes in which tutoring was not used.

Eighth grade students were classified as having inductive or deductive learning styles by Gawronski. She then gave them programs which were developed inductively or deductively. No significant differences in achievement were found between groups, whether or not they had programs compatible with their learning style.

Gussett found that materials for seventh graders which used "non-standard" English were as effective as regular text materials.

How do "modern" and "traditional" programs compare?

Norland compared sixth and eighth grade groups for the 1968-69 school year, who had five or more years of instruction using modern mathematics, with their counterparts for the 1964-65 school year, who had instruction using primarily traditional materials. In general, students who had a traditional program scored significantly higher on com-

putation tests, in six out of ten cases, than those who had a modern program. In only one case did significant differences favor the modern group. On tests of problem solving, the traditional groups were significantly higher in three of ten cases, and in only one case was the modern group significantly higher. In other cases, there were no significant differences.

What is the role of activity approaches in mathematics?

Vance and Kieren summarized recent research on mathematics laboratories by noting (1) the research indicates that students can learn mathematical ideas in laboratory settings; and (2) there is only limited evidence that laboratories promote better attitudes toward mathematics, though most students seem to prefer laboratory approaches to more class-oriented approaches.

Recent studies have not indicated that higher achievement can necessarily be expected from activity approaches. In a study with disadvantaged low achievers in grades 7 and 8, Cohen found that use of a conventional textbook/ chalkboard/discussion approach resulted in a significant increase in achievement, when compared with a group taught using a laboratory approach with a variety of manipulative and multi-sensory materials.

Johnson also reported on the use of activity-oriented lessons with seventh graders. Such instruction did not appear to be more effective than instruction with little or no emphasis on activities for units on number theory, geometry, measurement, and rational numbers, though activities did aid in the learning of some concepts by low and middle ability students.

What procedures are effective for geometry?

While research has been directed toward facets of each course in the secondary school mathematics program, many studies were focused on geometry. Kort evaluated an innovative transformation approach to geometry. For students in eleventh-grade mathematics classes, it was found that those who had studied tenth-grade geometry using a transformation approach showed some retention and transfer advantages over those students who had used a non-transformation approach in their study of tenth-grade geometry. He suggested that tenth-grade geometry should be changed to extensively utilize transformations only if subsequent mathematics courses are altered to capitalize on a background in geometric transformations.

Solheim found that the attitudes of tenth grade groups studying transformations of the plane became more negative over a five-week period, while those of groups studying traditional topics were unchanged. Attitude toward geometry and achievement in geometry were found to be significantly related.

Hershberger compared the effects of a vector and a non-vector approach used with analytic geometry students for thirteen days. No significant differences were found between the approaches on immediate achievement or retention measures, though those using the vector method did significantly better on the transfer test.

Martin, in a study with 2,000 tenth graders and 43 teachers, found no significant differences in the critical thinking skills of students using "ledger" or "flow-proof" methods of structuring proofs.

Lorentz reported that, for geometry content, material in which explanation followed definition was not as effective as material developed in an explanation-definition-explanation pattern, explanation preceding definition, or definition alone.

Does the learning of logic have a "pay-off"?

Shumway examined the effect of negative instances on the acquisition of mathematical concepts. In a 65-day study, one group of eighth graders was given both positive and negative instances of concepts pertaining to geometry, exponents, and operations, while the other group had only positive instances. Differences in performance favored the group having negative as well as positive instances. A "pay-off" from the inclusion of negative instances in the development of concepts pertaining to number operations appears to be a decreased tendency for students to overgeneralize properties associated with such operations.

Knowledge of symbolic logic (taught via programmed instruction) led geometry students to an improved understanding of the logic-based mathematics they had studied before learning the symbolic logic, and to following work. In algebra class, it took teacher encouragement along with a knowledge of symbolic logic, to produce significant results, according to Sharlow.

Roy used a unit on logic and proof to present the concept of validity and methodology of proof to one group of seniors, while a chapter of a college freshman text was used to present notions of informal reasoning and the nature of a deductive science or axiom system to another group. The groups were not different in their ability to determine the validity of given arguments or to prove theorems using the principle of mathematical induction.

In what ways are computers facilitating mathematical achievement?

A great amount of research attention was directed during the use of various aspects of computer-assisted instruction. This research dealt with both non-tutorial and tutorial CAI, as well as with the status of computer use in mathematics.

Bishop interviewed teachers from twenty schools which were using the computer in mathematics programs, and derived other data from a questionnaire returned by 100 teacher education institutions in Missouri and adjoining states. He found that 30 per cent of the secondary schools offered technically-oriented computer-related courses in their mathematics curriculum. Only one of the schools used computer-assisted instruction in a tutorial role. Twenty per cent used the available computer time for enrichment of and in support of courses previously existing in the mathematics curriculum. About two-thirds of the colleges included a computer-related mathematics course as a recommended part of the teacher education curriculum. The teachers felt that methodology in using computer time in their mathematics courses was their principal need.

In a study conducted by Ronan, students in one middle-ability algebra-trigonometry class used the computer for one semester as a computational tool, using the language BASIC. Their achievement was compared with that of students in a class which did not use the computer. There was no significant difference between the mean achievement of the two groups after study of (1) algebraic review material and radicals in equations, (2) trigonometric functions and complex numbers, and (3) circular functions and their inverses. The students who used the computer did attain a significantly higher level of achievement after study of exponential functions and logarithms. There was no significant difference between groups in ability to apply mathematical concepts or in problem-solving. Students who used a computer attained a significantly higher level of achievement in mathematical skills and in logic and reasoning ability than those who did not use a computer.

For two second-year algebra classes taught with computer applications (using BASIC), Hoffman found no evidence that use of the computer significantly affected generalization skills or achievement,. except for certain simple analysis skills.

Katz compared the effects of two computer-augmented methods of instruction with traditional instruction, using nine average-ability second-year algebra classes. One group wrote computer programs in conjunction with the regular classroom presentation of algebra. Programs were run on the computer by aides, and then returned to pupils. A second group also wrote computer programs, but ran their own programs on the computer, with time spent in the computer room taken from classroom instructional time. Those who ran their own programs scored significantly lower than the other experimental group or the regular instruction group on a full-year standardized test. On tests of only the topics that were related to computer-program-writing, there were no significant differences for any group. Katz concluded that the most effective method of computer utilization appeared to be program-writing with no direct computer access.

Pack also studied the effects of three modes of computer use: (1) time-sharing, involving conversational interaction between the computer and students who were simultaneously using it; and two batch procedures, in which students prepared programs on paper tape and submitted them to a monitor for batch processing—(2) quick batch, in which results were received within an average of eight minutes, and (3) slow batch, in which students received their results the following day. Thirty-six high-ability students rotated through the three modes, spending ten hours in each, working on a common set of problems. No significant differences were found in scores on a basic computer language test or on number of problems solved. Students preferred time-sharing, with quick batch as a second choice and slow batch least preferred.

In a study with 38 seniors, Ostheller found that those who were taught a unit on probability and statistics via a tutorial computer-assisted instruction program achieved as well as groups taught by programmed or regular textbooks. No significant differences were found in attitude, though students preferred student-teacher interaction to CAI.

A CAI program used in a one-semester ninth-grade mathematical skills course was found to be effective in improving computational skills in whole numbers, fractions, decimals, and per cent, and in improving attitude toward mathematics, Cole reported.

What type of homework is effective?

Laing found no significant differences in achievement and retention between eighth-grade groups in which practice on a topic was massed in one homework assignment or distributed over several. There was a consistent trend favoring distributed practices.

Urwiller found no significant differences in achievement or attitude between groups who used spiral homework assignments (with problems assigned at spaced intervals) or traditional homework assignments (with problems from each day's lesson as well as problems from previously-taught material) in second-year algebra. Both groups made significant gains during the year, and retained at the 98 per cent level over the summer.

Three modes of assistance used by students while doing geometry homework were studied by Lash. The group getting complete solutions achieved lower scores than groups getting hints or answers or no assistance.

What techniques are helpful in developing tests?

Coppedge and Hanna analyzed geometry test questions to determine the degree of agreement between distractors for multiple-choice items and the discriminating errors that students made on completion items. Students were administered a test in completion format; teachers were asked to generate three distractors to be used if the item were in a multiple-choice format. There was much variability in teachers' ability to provide the most discriminating distractors, and to differentiate popular distractors from highly discriminating distractors. It was suggested that, as an alternative way of improving the quality of multiple-choice tests, distractors be developed from wrong answers which discriminate between high and low achievers on tests in completion format.

Hanna also reported that multiple-choice items in which tenth-grade students selected (1) what was given and what was proved or (2) the "reason," were recommended over items which merely required the student to note whether a statement could be proved.

What is the affective status of students of mathematics?

Callahan reported that 20 per cent of the eighth graders he surveyed felt that they disliked mathematics, 18 per cent were neutral, while 62 per cent liked it. The need for mathematics in life was named most frequently as the reason for liking it; not being good in mathematics was cited most often as the reason for disliking it.

Data from the International Study of Educational Achievement indicate small correlations between achievement and attitude, reported Postlethwaite.

How may successful problem solvers be identified?

Dodson attempted to describe successful "insightful" mathematics problem-solvers, using evidence on tenth graders from the NLSMA data bank. Among the eleven "strongest" characteristics of successful problem-solvers were high scores on reasoning tests, good spatial relations ability, ability to discriminate critical elements, divergent thinking, low test anxiety, and a positive attitude toward mathematics. He made some suggestions for the development of insightful mathematics problem-solving ability, such as emphasis on solving geometry problems which require students to synthesize a large number of seemingly unrelated geometric ideas.

What patterns of teacher-behavior have been described?

Strickmeier described patterns of teacher verbal behaviors in seventh grade mathematics classes grouped by ability, and compared teachers' perceptions of their verbal behaviors and expectations of students for classes of different ability levels. He found that although the ten teachers he interviewed and observed had different perceptions and expectations for classes of different ability levels, such differences were not reflected by observable differences in the teachers' verbal behaviors.

Lockwood identified elements that would be helpful in explaining the question-asking behavior of teachers in the classroom. Using audio-tapes of 47 class sessions in grades 7 through 11 involving four carefully selected mathematics teachers, he identified 16 cues (stimuli which act as signals to ask a question) and 17 factors (elements that have an influence with respect to what question the teacher asks). He also identified, in terms of combinations of cues and factors, two general relations which were helpful in explaining and predicting teacher questioning: the "go-ahead" relation and the "modification" relation.

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*"DAI" refers to *Dissertation Abstracts International.*

A complete annotated listing of studies published during 1971 will be available both from the ERIC Information Analysis Center for Science, Mathematics, and Environmental Education and in the November 1972 issue of the *Journal for Research in Mathematics Education.*

Mathematics Laboratory Project Underway

The staff of ERIC/SMEAC has begun work on a special mathematics laboratory project. This project will identify and disseminate innovative practices in mathematics teaching via an activity or laboratory approach. The primary thrust of the project will be the preparation of a general handbook on mathematics laboratories and activity learning addressed to mathematics education specialists. This handbook will include rationale and objectives for activity learning in mathematics, a review of procedures for establishing activity learning programs in mathematics, a review of research on activity learning, and a large resource section containing descriptions and explicit instructions for activities for mathematics classes organized by content topic and grade level.

Mathematics education specialists will review and evaluate the general handbook. In accordance with their evaluations, the original resource materials in the handbook will be revised to form two target publications for classroom teachers of mathematics. These publications will be targeted to teachers of disadvantaged low-achievers in mathematics (grades K-9), and to teachers of exceptional children in mathematics (grades K-9). The two final resource publications will provide a new source of carefully evaluated teaching materials which have the potential of significantly changing educational practices in the teaching of mathematics to disadvantaged low-achieving students and to exceptional children (disabled or mentally handicapped students).

We are now well into the process of collecting noncommercial and teacher-made materials for mathematics laboratories, K-9. We are looking for printed materials, but we assume that most of these will describe some physical materials that can be easily obtained or constructed by classroom teachers. For the present we are interpreting "laboratory activities" in a very broad sense. Descriptions of teaching devices, sets of activity cards, equipment for demonstrations or games, and data sheets or work sheets are commonly provided. However we do not use problem sheets or problem lists that do not refer to some equipment or paper and pencil constructions as aids for problem solving. Our staff edits and adapts all the contributions to fit a standard format. We hope to provide very concise descriptions so that teachers can rapidly examine several ideas. To date, we have received approximately 2000 pages of materials from readers of our newsletter and from creative mathematics teachers they have identified for us. We would like to receive even more materials, however, and encourage our readers who have not already contributed to the project to do so now.

Many of the materials we have received are extensive self-contained laboratory units. These materials will be announced in future issues of **Research in Education** and will be available from the ERIC Document Reproduction Service. We anticipate that final versions of the project handbooks will be available by spring or summer, 1973. Future issues of the newsletter will contain progress reports for the project as well as the availability of materials.

About Mathematics Laboratories

Readers who are interested in our mathematics laboratory project will also be interested in a recent paper, **About Mathematics Laboratories,** announced in a recent issue of Research in Education. Authored by William M. Fitzgerald of Michigan State University, this 33 page paper traces the growth of the concept of a mathematics laboratory and reviews recent research and developments in this field. The first section quotes several interpretations of the term and discusses some of the activities advocated by its proponents. The second section quotes extensively from E. H. Moore (1902) and McLennan and Dewey (1895) to show that the idea is older than the present influence of Piaget, Bruner, Gattegno, etc. A section of quotations from more recent advocates of mathematics laboratories is followed by a review of research on the use of manipulative materials, desk-calculators, and science-linked courses; the correlation of motivation with achievement; and the practical difficulties of implementing a laboratory approach in a school. The final sections discuss laboratory materials and the use of laboratory methods in teacher training. The paper was originally commissioned by School Mathematics Study Group.

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Two New Prep Reports of Special Interest to Mathematics Educators

PREP (Putting Research into Educational Practice) is a series of monthly reports which synthesize and interpret research, development, and current best practice on specific educational topics. Intended as a format for disseminating significant findings to the practitioner quickly, these reports are targeted to specific educational audiences—the administrator, school board member, teacher, curriculum specialist, and teacher educator. The following recent PREP reports may be of special interest to mathematics educators.

PREP NO. 28: EDUCATIONAL PERFORMANCE CONTRACTING

PREP No. 28 reports on the general concepts of educational performance contracting, types of contracts, contracts selection, and some of the current programs in contracting for student achievement. It has been included in the PREP series in order to provide educators with research based findings on this new technique. It was adapted from a study on performance contracting which was conducted for HEW by J. P. Stucker and G. R. Hall of the Rand Corporation, Santa Monica, California.

PREP NO. 30: TEACHING RESOURCES FOR LOW-ACHIEVING MATHEMATICS CLASSES

The ERIC/SMEAC paper, Teaching Resources for Low-Achieving Mathematics Classes, by Kenneth J. Travers, John W. LeDuc, and Garth E. Runion has now been adapted as No. 30 in the series of PREP Reports. As a result, this paper, which we announced in our previous newsletter, will have a wide distribution among educational practitioners. The paper reviews teaching approaches and general resource materials for low achievers in both elementary and secondary school mathematics classes. Two bibliographies are included.

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